Atmospheric Breathing Electric Thruster for Planetary Exploration

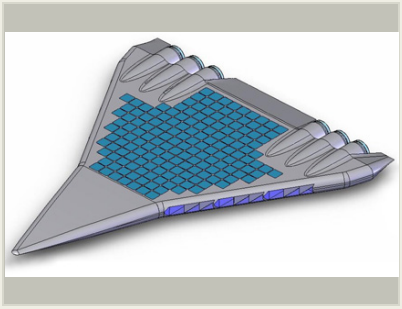
Completed Technology Project (2011 - 2012)

Project Introduction

This study will investigate the development of an atmosphere-breathing electric propulsion solar-powered vehicle to explore planets such as Mars. The vehicle would use atmospheric gas for propellant, eliminating the need to launch and carry the propellant from Earth. The propulsion thruster would be electric where the gas is ionized in a plasma and accelerated by electromagnetic fields. The combination of high efficiency and high specific impulse of the electric propulsion thruster and free propellant in-situ will result in an exciting and enabling technology. At the completion of this development, NASA will be able to perform missions of extended lifetime and capabilities beyond those available by typical chemical rockets. Phase I will formulate feasibility of the concept through modeling, calculations and preliminary laboratory experiments and push validity into Phase II research.

Anticipated Benefits

Low altitude Mars orbiting spacecraft is of scientific interest to NASA and the space community. Some atmospheric measurements can only be made in-situ. On Earth, these measurements are typically performed by sounding rockets or very high altitude balloons. A spacecraft orbiting Mars at these low orbits will require significant drag makeup and carrying that much propellant from Earth is prohibitive. Developing a Mars atmosphere fed thruster can open up a new set of missions that are of extreme scientific interest. In addition to the atmospheric measurements, surface observation and polar orbits will be of interest.#An Earth based ABHET can be utilized for many atmospheric monitoring and measurement applications of interest to NASA. Real time and continuous monitoring of Earths atmosphere is beneficial to understanding the complex atmospheric weather. The high drag of LEO orbits in the 150km range is difficult to manage with typical spacecraft and much too light on oxygen for typical air combustion engines.



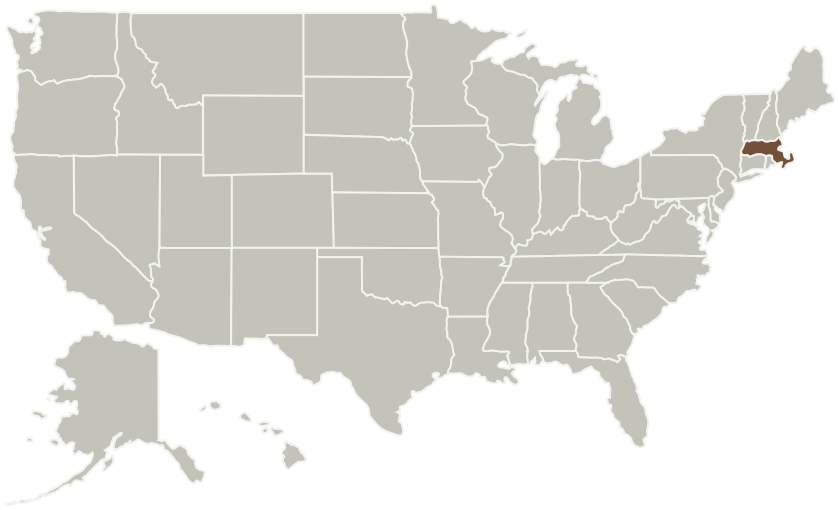
Project Image Atmospheric Breathing Electric Thruster for Planetary Exploration

Table of Contents

Atmospheric Breathing Electric Thruster for Planetary Exploration

Completed Technology Project (2011 - 2012)

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Busek Company, Inc.	Lead Organization	Industry Women-Owned Small Business (WOSB)	Natick, Massachusetts

Primary U.S. Work Locations
Massachusetts

Project Transitions

September 2011: Project Start

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

Busek Company, Inc.

Responsible Program:

NASA Innovative Advanced Concepts

Project Management

Program Director:

Jason E Derleth

Program Manager:

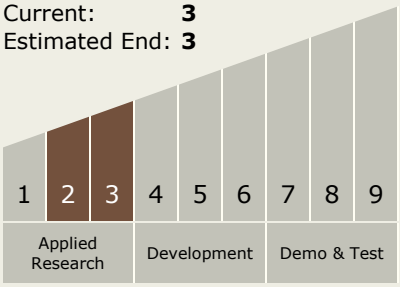
Eric A Eberly

Principal Investigator:

Kurt Hohman

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Atmospheric Breathing Electric Thruster for Planetary Exploration

Completed Technology Project (2011 - 2012)

September 2012: Closed out

Closeout Summary: The objective of this phase of the program was to show fe asibility of a Martian atmosphere breathing Hall effect thruster (MABHET). To ac complish this objective, we set out to demonstrate that: 1) a Busek Hall effect t hruster could operate on the Mars atmospheric gases, 2) the atmospheric condit ions and orbital parameters required for the MABHET were indeed achievable, 3) further advancement of the inlet concept held credible, and 4) continued investi gation into the remaining vehicle components including the cathode, power gene ration, size/mass and science remained feasible. We achieved all of these goals during the first phase of this program. One major achievement during this phase was the operation of a Busek HET with simulated Mars atmosphere. Two goals in cluded an overall efficiency of at least 20% and a maximum thrust to power rati o since the vehicle would likely be power limited. The HET was operated over a wide range of mass flow, applied anode voltage and overall power, simulating va rious potential altitudes and size of the thruster. Definitive thrust measurements prove that 20% efficiency is indeed possible and likely on the low end of expecte d performance. The thrust to power ratio peaked around 30mN/kW with an effici ency around 22-25%, depending on the operating conditions. This measured per formance with be discussed in more detail below. Sizing of the vehicle, propulsio n system and Mars atmosphere conditions also need to be confirmed that such a concept is feasible. The major drivers of this analysis are the vehicle drag and s olar flux/collection. Utilizing current technology for spacecraft drag and solar arr ays, the MABHET concept is right on the edge of feasibility. However, solar array s are becoming more efficient on a study pace and drag in rarefied atmospheres is also becoming better understood. Minor improvements, in either or both of th ese areas, will confirm credibility to MABHET feasibility for future missions. The atmospheric inlet or propellant collector is a critical component for the MABHET concept to work. We chose to further our investigation of the inlet numerically u tilizing DSMC and we found that shrinking the inlet proportionally for a smaller t hruster/vehicle design also held performance, thus the focus on a lower power, smaller vehicle was also feasible. The inlet is the lead critical path component an d needs to be investigated early in future programs. Finally, analysis and some experiments on the remaining propulsion system components and spacecraft de sign were initialized during phase I. This included some radio frequency cathode tests performed by Colorado State University. Though these tests were unsucces sful, rational for the failure and a path to success has been determined. We also began looking at the science made possible by this concept and who in the scien ce community might be interested. Solar array advances and possible low drag s urfaces are discussed.

Technology Areas

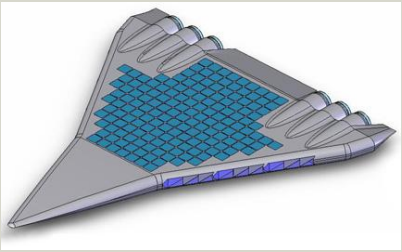
Primary:

- TX01 Propulsion Systems
  - TX01.2 Electric Space Propulsion
    - TX01.2.3 Electromagnetic

Target Destinations

Mars, Others Inside the Solar System

Images



15117.jpg
Project Image Atmospheric Breathing Electric Thruster for Planetary Exploration
(https://techport.nasa.gov/image/102287)